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Corrigendum

Corrigendum to "Greenhouse gas emissions from agricultural food production to supply Indian diets: Implications for climate change mitigation" [Agric. Ecosyst. Environ. 237 (2017) 234–241]

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The paper by Vetter et al. (2017) presented greenhouse gas (GHG) emissions associated with the production of major food commodities in India. Emissions of GHGs were calculated using the Cool Farm Tool and were based on farm management data for major crops (including cereals like wheat and rice, pulses, potatoes, fruits and vegetables) and livestock-based products (milk, eggs, chicken and mutton meat).

Methods correction

We corrected the calculated emissions by fixing errors in the model script and refined the methodological approach to accommodate the fixes. The correction included (i) fixing an error in application of the Stehfest and Bouwman (2006) model for calculating the N_2O emissions, (ii) fixing a double counting of methane emissions for rice *per* kg production, (iii) excluding data points for plots with zero recorded yield (to avoid division by zero in carbon footprints), (iv) choosing appropriate crop classes for cotton and sugarcane, and (v) fix the percentage of rice under flooding conditions as previously it was not representative of the area under this management.

Livestock emissions were revised after additional discussion with livestock experts. The new feed emissions were based on the amended GHG emissions of the crops, and the GHG emissions from enteric fermentation and manure were adjusted to match the Indian dataset in Herrero et al. 2013.

For each crop and livestock species, weighted average emissions were calculated considering state-level total area under crop obtained from the Directorate of Economics and Statistics of the Government of India (http://eands.dacnet.nic.in) and total number of animals obtained from the 19th livestock census of the Government of India (GOI, 2012).

Results update

GHG emissions of food items up to farm-gate

The updated results are given in Table 1 and Fig. 2.

For paddy rice, > 10,000 plots were available for analysis with a wide range of management practices, which is reflected in the GHG emission results (Fig. 2B). The main reason for the wide range in GHG emissions seen in rice was water management, the main determinant of CH_4 emissions. In particular, continuous flooding generated the highest CH_4 emissions, while longer and more frequent periods of drying reduced emissions. For example, changing the water regime from continuously flooded to multiple drying of the field, reduced CH_4 emissions 9-fold (data not shown). The GHG emissions weighted by state level area gave a value of 2408 kg ha^{-1}.

Emissions of GHGs *per* kg product i.e. GHG emission intensity (Fig. 2C) varied markedly between livestock types. Emissions were highest for mutton meat (as the example for ruminant meat), followed by other livestock products such as dairy (milk) and poultry products (eggs, poultry meat). Emissions intensities were greater for livestock products than for crops. Mean GHG emissions were < 0.8 kg CO_2eq kg^{-1} product for all crops.

The intensity of GHG emissions among crops was greatest in rice (0.73 kg CO_2eq kg^{-1}), followed by the group of other pulses. Greater GHG emissions intensity in pulses was mainly because of lower yield compared to other crop items. Intensities of GHG emissions from other crop groups were lower in the order of pulses, nuts and oils, cereals, fruits, roots and vegetables.

GHG emissions from food consumption in India

Fig. 3A shows relative reported consumption by weight of commodities in the Indian Migration Study (IMS), while 3B shows their relative contribution to emissions. Livestock products other than ruminant meat (principally milk, poultry and eggs) contributed the most to total dietary GHG emissions. Although ruminant meat had the greatest GHG emissions *per* unit product, it contributed less to overall GHG emissions (21.7%) as consumption was low, accounting for only

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Table 1
Major crops and livestock products by % of total intake in India, number of data points available with management information, averaged yield data, nitrogen input and GHG emissions *per* hectare, *per* kg of product and *per* kcal. Emissions are also weighted by production area.

food item	group	subgroup	% consumption of total food in Indian diets	nr. of data points	yield [tonnes/ha]	std dev	N [kg/ha]	std dev	GHG [kg ha^{-1}]	std dev	GHG (production area weighted average) [kg ha^{-1}]	GHG [kg kg^{-1} yield]	std dev	GHG (production area weighted average) [kg kg^{-1}]	GHG [kg 1000 $kcal^{-1}$]	std dev	GHG (production area weighted average) [kg 1000 $kcal^{-1}$]
Milk	Livestock product	Dairy - lo-fat	18.17	105								2.40		1.70	2.76		2.79
Wheat	Cereals	Cereals	9.42	6017	3.26	1.14	139.41	51.47	920.84	303.83	940.55	0.32	0.19	0.30	0.11	0.07	0.10
Paddy Rice	Rice	Cereals	8.97	11993	3.61	1.51	114.37	54.21	2572.17	2420.94	2407.47	0.80	0.87	0.73	2.04	3.78	0.28
Mango[a]	Fruit	Fruit	4.60	/	10.4	/	11.7	/	295.82			0.03			0.06		
Onion	Other	Spices	3.72	48	19.55	8.59	192.57	98.24	1386.96	644.22	1120.02	0.13	0.34	0.39	0.58	1.28	1.63
Tomato[a]	Other	Vegetable	3.67	/	130	/	360	/	1713.40			0.01			0.08		
Potato	Potato	Tuber	2.69	394	23.83	9.27	236.01	181.24	1687.12	731.75	1516.53	0.08	0.03	0.07	0.26	0.24	0.09
Orange[a]	Fruit	Fruit	2.57	/	10.3	/	113	/	1225.09			0.12			0.35		
Sugarcane	Other	Other	1.90	1312	79.35	33.49	258.84	122.67	2535.65	987.28	2364.98	0.03	0.01	0.03	0.82	1.37	0.31
Lentil	Pulses	Pulses	1.89	425	0.90	0.39	16.03	14.96	373.19	154.84		0.50	0.30		0.12	0.12	0.00
Spinach[a]	Other	Vegetable	1.29	/	21	/	33.5	/	328.32			0.02			0.10		
Peas	Pulses	Pulses	1.17	128	1.39	0.75	41.41	38.11	423.03	223.32	511.40	0.36	0.22	0.52	0.93	0.70	1.69
Poultry	Livestock product	Chicken	0.74	69								2.59		0.78	0.42		0.42
Egg	Livestock product	Egg	0.45	69								2.59		0.78	0.56		0.56
Groundnut	Pulses	Nuts	0.39	629	1.36	0.73	50.66	44.71	513.56	245.49	542.66	0.51	0.49	0.62	0.11	0.12	0.11
Mutton	Ruminant meat	Meat	0.38	280								45.10		39.90	17.15		15.17
Spices (Cumin Seed) [a]	Other	Nuts and oils	0.08	/	2	/	100	/	774.73			0.39			0.13		
Other Cereals[b]	Cereals	Cereals	2.76	3520	1.94	1.41	64.43	53.65	484.48	295.90		0.34	0.41		0.09	0.12	
Other Pulses[c]	Pulses	Pulses	3.8	3720	0.82	0.57	25.14	36.50	395.47	255.48		0.78	1.37		0.16	0.20	
Crops for vegetable oils[d]	Other	Nuts and oils	2.84	2569	1.30	0.62	40.66	36.20	504.16	231.39		0.54	0.62		0.11	0.16	

[a] No plot/farm data were available; typical management and statistical information were used to generate management information.
[b] Includes bajra, barley, maize, ragi and jowar.
[c] Includes black, red and green gram.
[d] Includes coconut, rapeseed, soybean, safflower, sesamum, sunflower.

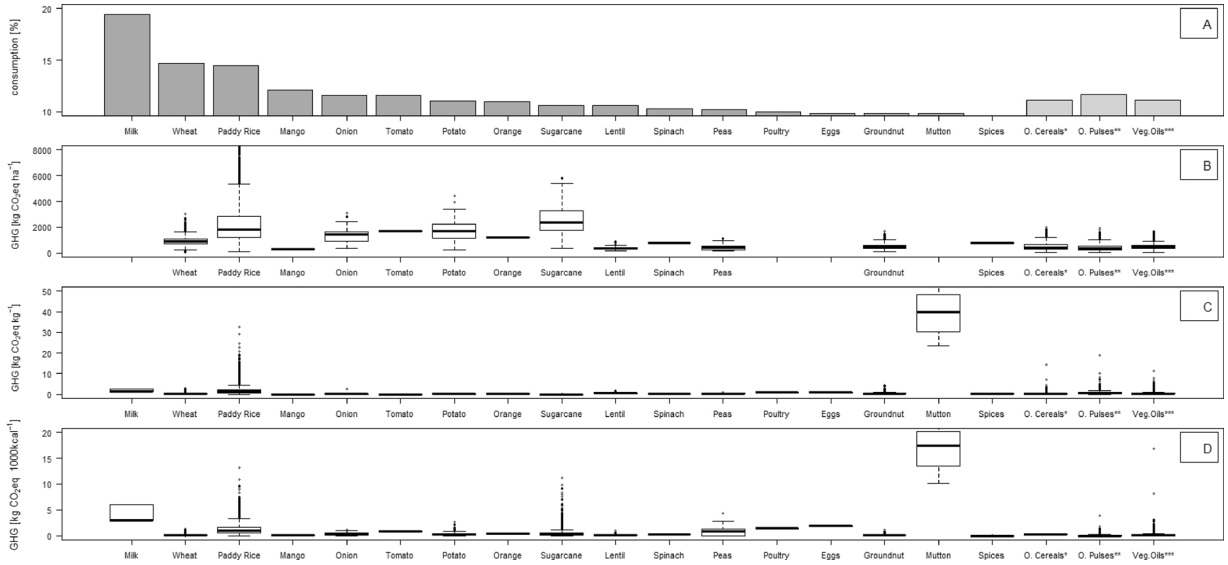

Fig. 2. (A) mass of food group consumption as a %-age of total consumption reported in the Indian Migration Study (Bowen et al. 2011); (B) GHG emissions associated with production of food groups in India per hectare, (C) per kg yield, (D) per 1000 kcal. Boxplots display the distribution of data at plot level where agronomic and management data were available (*Other Cereals: includes bajra, barley, maize, ragi and jowar; ** Other Pulses: includes black, red and green gram; *** Crops for vegetable oils: includes coconut, rapeseed, soybean, safflower, sesamum, sunflower).

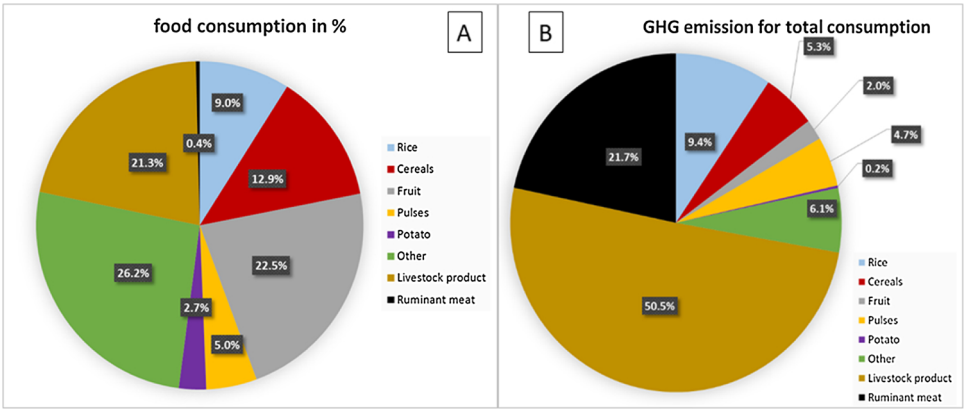

Fig. 3. (A) Proportion of consumption of food groups in Indian diets, and (B) distribution of GHG emissions from agricultural production of this diet.

0.4% of the mass of total food intake. Rice was the third largest contributor to total emissions (9.4%). Cereals other than rice and fruit products accounted for 12.9% and 22.5% of reported consumption by weight, respectively, yet as their emissions *per* unit of product were low, they made a relatively small contribution to total dietary GHG emissions, representing only 5.3% and 2% of total emissions, respectively. The groups "other" (including various crops from the subgroups nuts and oils, spices, and vegetables), potato and pulses also contributed little to total dietary GHG emissions compared to livestock.

Amended discussion

GHG emissions from livestock products

Emissions of GHGs associated with livestock products depended largely on feed inputs, and in other studies had been shown to range between 0.8–2.4 kg CO_2eq kg^{-1} milk, 1.7–6.6 kg CO_2eq kg^{-1} eggs, 2.5–6.9 kg CO_2eq kg^{-1} poultry meat and 10–20 kg CO_2eq kg^{-1} mutton and lamb (Bellarby et al., 2013). Most of these values came from model-based studies which focused on Europe. Our results for milk in India were within the range of these studies. The calculated emissions of poultry products were lower than in the above studies, but gave similar results to those reported by Pathak et al. (2010). The GHG emissions for mutton were greater, resulting from embedded emissions in feed, which were 50–75% of the total GHG emissions *per*-animal-*per*-year.

GHG emissions associated with Indian diets

Overall, national GHG emissions associated with diets were greatest for livestock products such as milk and eggs (Fig. 3), because these were widely consumed products with high GHG emissions *per* unit of product. Although there was limited consumption of ruminant meat in India, its high GHG intensity means that it was the second greatest contributor to GHG emissions.

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